Video Article

# A Detailed Protocol for Physiological Parameters Acquisition and Analysis in Neurosurgical Critical Patients

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## Abstract

Intracranial pressure (ICP) monitoring is now widely used in neurosurgical critical patients. Besides mean ICP value, the ICP derived parameters such as ICP waveform, amplitude of pulse (AMP), the correlation of ICP amplitude and ICP mean (RAP), pressure reactivity index (PRx), ICP and arterial blood pressure (ABP) wave amplitude correlation (IAAC), and so on, can reflect intracranial status, predict prognosis, and can also be used as guidance of proper treatment. However, most of the clinicians focus only on the mean ICP value while ignoring these parameters because of the limitations of the current devices. We have recently developed a multimodality monitoring system to address these drawbacks. This portable, user-friendly system will use a data collecting and storing device to continuously acquire patients' physiological parameters first, *i.e.*, ABP, ICP, and oxygen saturation, and then analyze these physiological parameters. We hope that the multimodality monitoring system will be accepted as a key measure to monitor physiological parameters, to analyze the current clinical status, and to predict the prognosis of the neurosurgical critical patients.

## Video Link

The video component of this article can be found at https://www.jove.com/video/56388/

## Introduction

ICP monitoring is widely used to evaluate intracranial status in neurosurgery department, especially in neurosurgical critical patients[1,2,3]. Besides mean ICP value, the ICP derived parameters such as ICP waveform, AMP, RAP, PRx, IAAC, and so on, can reflect the status of intracerebral circulation, cerebrospinal compensatory reserve, and brain compliance[4,5,6,7,8,9,10,11,12,13]. They can be indicative of impending neurological deterioration and even outcome of patients[14,15,16,17,18]. They can also be used as guidance of proper treatment[19]. However, most of the clinicians focus only on the mean ICP value while ignoring these parameters. This is partly because there are few specific devices that are suitable for clinicians in their daily clinical work.

To address these drawbacks, we have recently developed a multimodality monitoring system. We use an automatic data collecting and storing device to continuously acquire patients' physiological information such as blood pressure, ICP, and oxygen saturation, and analyze these physiological parameters in order to reveal the current clinical status and, hopefully, predict the prognosis of the neurosurgical critical patients. This multimodality monitoring system has several advantages: (1) it can collect real-time data at high frequency, (2) it can record multiple parameters, *i.e.*, ICP waveform, PRx, RAP, and IAAC, (3) it can achieve long term continuous monitoring, and (4) it is portable and easy to learn.

The objective of this article, therefore, is to show a detailed method of how to use the multimodality monitoring system to record various physiological parameters in neurosurgical critical patients.

## Protocol

This protocol was approved by the Institutional Review Board of Renji Hospital, Shanghai Jiaotong University School of Medicine.

### 1. Preparation of the Patient

NOTE: ICP sensor is placed in the patient by a surgical operation (**Figure 1**). The sensor is placed in the epidural space, subdural space, parenchyma, or ventricular system.

1. Connect the ICP monitoring machine with the bedside monitor via a specific communication cable.
2. Adjust the reference of patient's bedside monitor, so that the data from the bedside monitor are in accordance with the ICP monitoring machine.

 

3. Perform an arterial line placement on patient's left or right radial artery[20].
4. Connect the arterial line with the baroreceptor.
5. Connect the pressure transducer with patient's bedside monitor via a communication cable.
6. Zero adjust the bedside monitor so that the measured blood pressure coincides with the actual value.

## 2. Recording of Physiological Parameters

1. Connect the patient's bedside monitor with the data collecting and storing device via a network cable.
2. Press the power button to turn on the data collecting device.
3. Wait for a few seconds until the multimodality monitoring software runs automatically.
4. Enter the information of the patient, including the name, ID, diagnosis, and initial Glasgow Coma Scale (GCS).
5. Click the "Save and start monitoring" button to start data collecting and storing.
6. Click the "Turn off" button on the screen at the end of the data acquisition (**Figure 2**).
7. Enter the final GCS.

## 3. Parameter Analysis

1. Dump the stored data to a U-disk through universal serial bus (USB) interfaces on the host.
2. Enter a user name and password to log in to the analysis server.
3. Click the "Create new record" button and select the data file in the U-disk to start uploading.
4. Wait for around 10 to 20 min before the data are analyzed (depending on the data size).
5. Click the "Detail" button of each record to see the result.
6. Click the "Chart viewing" to see the final diagram.
7. Drag the timeline to see more detail.
8. Click the "scattergram" button to see the distribution of the parameters.

## Representative Results

This new multimodality monitoring system was applied on 22 neurosurgical critical patients (15 males). 12 of them (54.55%) had suffered from traumatic brain injury (TBI), 9 of them (40.91%) had intracranial hemorrhage and 1 of them (4.55%) had severe cerebral infarction. The total monitoring time is more than 1,900 h (about 88 h per patient). After successful surgery, we continuously monitored and analyzed their ICP, BP, CPP, PRx, RAP, and IAAC. **Figure 3** shows representative data from this monitoring system. We can adjust the timeline to see more detailed information (**Figure 4**). Besides, we are able to analyze the relationship between any two parameters, which is demonstrated in **Figure 5**.

**Figure 1: ICP sensor placement.** The patient undergoes an operation for ICP sensor placement before monitoring. The sensor can be placed in the epidural space, subdural space, parenchyma, or ventricular system. This figure shows ventricular puncture and sensor placement. The ICP sensor is located at the tip of the catheter. Please click here to view a larger version of this figure.


**Figure 2: Screen of monitoring system.** The upper left area shows current ICP waveform and blood pressure. The lower left area shows current RAP, PRx, IAAC, CPP, and AMP. The right part of the screen shows the history. Shown at the bottom are some of the functional buttons such as output, screen shot, and adding markers. Please click here to view a larger version of this figure.

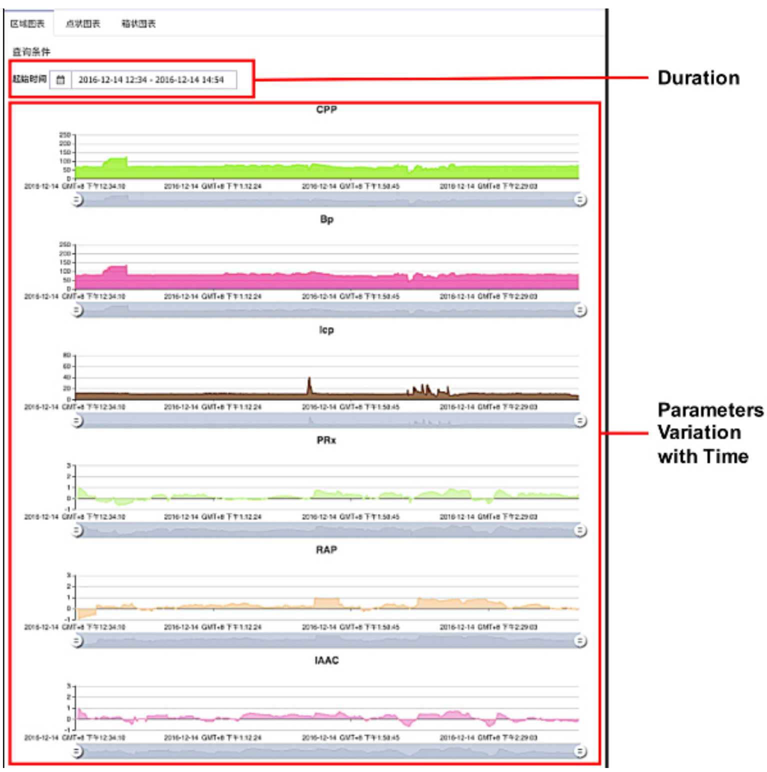


**Figure 3: Representative data of a cerebral hemorrhage patient.** The parameters such as ICP, BP, CPP, PRx, RAP, and IAAC are recorded and plotted. The X axis is the timeline and the Y axes are the separate parameters. Please click here to view a larger version of this figure.

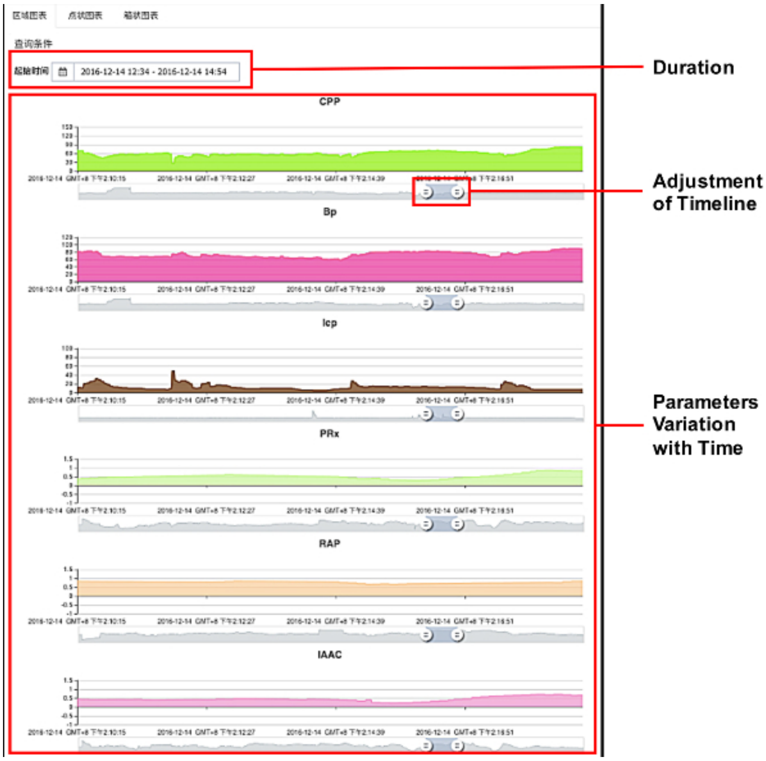


**Figure 4: Detailed information of representative data.** As we adjust the timeline, we can see more detail. The X axis is the timeline and the Y axes are the separate parameters. Please click here to view a larger version of this figure.


**Figure 5: Relationship between ICP and PRx.** We can change the parameters on the X axis and Y axis to analyze the relationship between any two parameters. In this figure, the X axis is the ICP and the Y axis is the PRx. Each red dot represents a real-time record. We can see that, in this patient, his PRx has a variation from -0.7 to 1 and the lowest PRx is reached when his ICP is 10 mmHg. Please click here to view a larger version of this figure.

## Discussion

This aim of this article is to introduce the new multimodality monitoring and analyzing system for neurosurgical critical patients, which can be used to monitor physiological parameters, analyze the current clinical status and, hopefully, predict the prognosis of the neurosurgical critical patients. Nowadays, the focus of ICP monitoring is mainly on the mean ICP value while ignoring other parameters, which may carry risks of inaccuracy or delay[4,5,21]. On the other hand, the ICP derived parameters such as ICP waveform, AMP, RAP, PRx, and IAAC are reported to have great significance in predicting prognosis and guiding proper treatment[5,16,17,18,19]. However, all these parameters require multimodality monitoring and big data acquisition and analysis, which can take up a lot of time and effort. Besides, there are few specific devices that are suitable for clinicians in their daily clinical work currently.

In order to solve this problem, we recently developed a multimodality monitoring system. It uses an automatic data collecting and storing device to continuously acquire patients' physiological information before sending the data to the online server for analysis work to investigate the meaning of these ICP derived parameters. As is mentioned previously, the multimodality monitoring system has the following advantages. First of all, it can collect real-time data at a high frequency. The frequency of data collection can reach up to 120 Hz. Secondly, it can record multiple parameters, *i.e.*, ICP waveform, PRx, RAP, and IAAC. All of them are critical in the analysis of current clinical status and in the prediction of prognosis. Moreover, it can achieve long term continuous monitoring. It can record all the details throughout the treatment of patients. Last but not least, it is portable and easy to learn. Clinicians can easily upload the data to a specific analysis server, which will perform the calculation and graphic construction automatically. There are only two critical steps in the protocol. One is the placement of ICP sensor. The other is the arterial line placement and arterial blood pressure monitoring. Once correctly connected and operated, the multimodality monitoring system can collect and store real-time data before analyzing and graphing them automatically, which is suitable for clinicians.

However, it also has some limitations. This system only includes ICP and invasive blood pressure and lacks other parameters such as EKG, EEG, or TCD. Another limitation is that the automatic analysis mode is not abundant, and can only do certain calculations and graphic constructions.

We have been continuously modifying this system and have fixed several problems that occurred during the long-term use. We are confident that all the limitations will be addressed in the future and it will be more applicable.

We hope that the multimodality monitoring system will be accepted as a key measure to monitor physiological parameters, to analyze the current clinical status, and to predict the prognosis of neurosurgical critical patients in the future.

## Disclosures

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